INCREASING FOLLOWING HEADWAY WITH PROMPTS, GOAL SETTING, AND FEEDBACK IN A DRIVING SIMULATOR

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We evaluated the effects of prompting, goal setting, and feedback on following headway of young drivers in a simulated driving environment and assessed whether changes produced in following headway were associated with reductions in hard braking when drivers were and were not using cell phones. Participants were 4 university students. During baseline, drivers spent half of the time talking on cell phones while driving. At the start of the intervention, drivers were prompted to increase following headway while on the cell phones and were provided a specific target for following headway. Drivers were given feedback on increasing following headway when on cell phones at the end of each session. The intervention package was associated with an increase in following headway and a decrease in hard braking when participants were on and off the cell phones. Cell phone use did not affect any of the measures.

Key words: cell phone use, driving simulator, feedback, following headway, goal setting, prompts, tailgating

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One of the major contributors to collisions is a following headway that is too short to allow the following driver to react appropriately to sudden braking by the lead vehicle (Taieb-Maimon & Shinar, 2001). The headway between two moving vehicles can be expressed in terms of time. The following headway is the time that elapses from when the lead vehicle's rear bumper crosses a stationary object on the road to the time the following vehicle's front bumper crosses the same stationary object. Several driver training programs state that 2 s is the minimum headway for safe following, which is frequently referred to as the "two-second rule" (Michael, Leeming, & Dwyer, 2000). In the United States, the recommended following headway varies from 2 to 3 s in different states.

Studies of drivers in the United States have shown that headways of 1 s or less may be much closer to the norm. Evans and Wasielewski (1983) showed a correlation between driving headway and crash involvement. A higher percentage of drivers with a crash history have headways of less than 1 s compared to accident-free drivers. Following too closely to a lead vehicle decreases the time available to react to a situation that requires braking. Driver safety is compromised further when additional distractions, such as cell phone use, further increase reaction time of the following driver.

Cell phone use while driving has caused major concern in the driver-distraction literature (AAA Foundation for Traffic Safety, 2008). Alm and Nilsson (1995) evaluated the effects of engagement in a cell phone task during a driving simulation and found that cell phone conversations increased reaction time. Strayer and Johnston (2001) investigated the effects of both hands-free and handheld cell phone conversations on performance during simulated driving tasks and found a higher probability of missed red lights with both types of cell phones. These studies document some negative effects of cell phone use while driving, but other studies have suggested that cell phone use might not be as problematic.

Shinar, Tractinsky, and Compton (2005) found that driving performance while using a cell phone may improve with continued

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practice. Another study by the U.S. Department of Transportation was conducted to investigate driver distraction in commercial motor vehicle operations. Data from two large-scale truck-driving studies were combined and analyzed. Results indicated that talking on or listening to a cell phone during driving was not associated with increased risk (Olson, Hanowski, Hickman, & Bocanegra, 2009). Thus, it is possible that the detrimental effects of cell phone use have been overestimated in previous studies.

Continued study of the effects of cell phone use under simulated conditions may help to identify the conditions under which cell phone use is problematic. However, in most research on cell phone use and driving, drivers completed artificial cell phone tasks rather than engaging in normal conversation. For example, McKnight and McKnight (1993) asked participants to solve math equations, which served as a distracting task and surrogate for normal conversation. Alm and Nilsson (1995) used a complex working-memory task in which the participants in the experimental groups labeled sentences as meaningful or nonsensical. The effect of these tasks on driving may be dissimilar to those of cell phone conversations. Drivers may pace their driving (e.g., decrease speed if involved in a demanding conversation) to accommodate the demands of a phone conversation and partially pace the phone conversation (e.g., pause before responding) to accommodate driving demands (Shinar et al., 2005). In studies using artificial tasks, participants were not able to make these adjustments because the experimenter set the pace of the driving task and the distracting task.

Although some studies have examined the relation between following too closely and the increased risk of a crash, none have evaluated the effectiveness of behavioral training procedures to increase driver following headway. However, many studies have documented the efficacy of prompting and feedback to increase other safety-related behaviors. For example, Austin, Hackett, Gravina, and Lebbon (2006) used prompts and feedback to increase coming to a full stop at stop signs, and Rantz, Dickinson, Sinclair, and Van Houten (2009) increased pilot checklist use and accuracy using prompting and feedback. The purposes of the present study were (a) to examine the effects of prompting, goal setting, and feedback on driver following headway; (b) to determine whether increased following headway was associated with a reduction in hard braking; and (c) to assess the effects of a cell phone conversation during baseline and intervention.

METHOD

Participants and Setting

Participants were four college students from a midwestern university in the United States. All participants were drivers with limited driving experience. Three participants were 18 years of age at the beginning of the study; the fourth was 19 years old. The duration of the study was 5 months, and the participants came in every week for sessions that lasted 1 hr. Intervention and the withdrawal phase were separated by 1 week. All participants were asked to drive a generic scenario in the driving simulator for approximately 20 min before beginning the study to identify drivers with short following headways. The generic scenario consisted of driving on a two-lane road traveling 45 mph (72 kph) in urban traffic. This scenario ensured that the driving behavior of the participants was consistent with the purpose of the study and allowed the participants to grow accustomed to driving the simulator using the brake and pedal configuration.

To qualify for participation, volunteers had to follow the lead vehicle with a mean following headway of less than 2 s while talking on a cell phone. If a participant's following headway was 2 s or more, he or she was excluded from the study. This was done to ensure that there was sufficient room for improvement in following headway. The experimenter tested 15 drivers to obtain four participants who met the inclusion criteria.

The setting was a driving simulation laboratory on campus. The simulator was housed in a room (3.05 m by 3.65 m) whose walls were painted flat black. A projection screen (1.6 m by 1.3 m) was attached to one wall. A high-resolution projector was attached to the opposite wall and displayed the driving scenario on the screen.

Apparatus

A Windows XP operating system was used for the simulation. The simulator was run on a STISIMS Drive system. The hardware consisted of force-modulated wheel and pedals. The entire seat, wheel, and pedal configuration was based on measurements from a small compact vehicle, and the seats were fully adjustable. Prior to each session, the operating system, cell phone, wheel and pedals, and STISIMS drive program were tested to ensure that the equipment was working appropriately. Hand-held cell phones were used to call the participants.

Scenarios

In each session, the participant drove one of eight programmed scenarios that were presented in a random order. The scenarios consisted of a two-lane road with multiple vehicles parked on both sides of the road. Do-not-pass signs, a double yellow line, and speed limit signs were posted throughout the scenario. Houses, buildings, and trees as well as other stationary objects along the side of the road were programmed to simulate an urban setting. Steady streams of oncoming vehicles were included throughout the scenarios. Weather was also programmable and consisted of normal blue skies with no wind or rain that could influence drivability.

When driving the simulator, the participants met a stream of oncoming vehicles. The traffic on the road heading in the same direction as the simulator vehicle consisted of one lead vehicle that was programmed to merge onto the roadway at the start of the scenario and consistently traveled at a speed of 45 mph (72 kph). Depending on the scenario, other vehicles merged in and out of traffic, which resulted in lead-vehicle braking. The participants were instructed that they were prohibited to pass the lead vehicle during the scenario and were asked to follow this vehicle until the end of the scenario.

Response Measurement and Procedural Integrity

Data were automatically collected by the STISIMS software program and saved in a file format at the end of each session. The data were then imported into Microsoft Excel. Interobserver agreement was not assessed because data were recorded automatically. Following headway (in seconds) was calculated from the results by dividing the following distance, displayed on the results simulator summary page, by the vehicle speed also obtained from the summary page, and then dividing this by the conversion factor 1.47 ft/s (e.g., 198 ft/45 mph/1.47 ft/s = 3 s). Mean braking deceleration, measured in ft/s^2, was automatically calculated and reported in the summary log produced by the driving simulator. Participants were not given any feedback on mean braking deceleration. Hard braking was defined as braking with a decelerative rate of 9 ft/s^2 or more; anything less than this is considered normal braking.

Participants initialed a checklist indicating that they had been given feedback by the examiner before and after the intervention session as a measure of treatment integrity; treatment integrity for feedback was 100%.

General Procedure

Participants drove the scenarios on the simulator each week. They spent half of the time driving while talking on a cell phone and half of the time driving without talking on the cell phone, alternating between 2.5-min periods on and off the cell phone. The cell phone conversations consisted of a list of 54 topics including restaurants, jobs, hobbies, pets, books, food, music, and movies. The participant read over the list of topics before the start of the experiment and agreed to the entire list of topics. Some topics were added throughout the experiment, and the list was read to the participants again for agreement. Participants could also indicate when they did not wish to talk about a certain topic by saying "pass" during the conversation. A research assistant was assigned to each participant and made the calls during each session. The calls were the same during all phases of the study. Each participant answered promptly to each phone call without hesitation. The research assistant was instructed to call the participant every 2.5 min and converse about the list of topics or another topic introduced by the participant. The research assistant was asked to speak to the participant and have a flowing conversation similar to an everyday phone conversation. Participants were allowed to pause in conversation because they were conversing rather than answering timed questions. Topics were changed when the research assistant and participant did not have anything more to say relating to the topic, as determined by the research assistant. Data were not collected on the integrity of the cell phone calls.

Participants drove one of eight scenarios that lasted approximately 10 min during each session. The scenarios consisted of following a lead vehicle on a two-lane road with moderate traffic. During the scenario, eight random events occurred, such as a car pulling out from the side of the road or a pedestrian crossing the street. Four of these events were scheduled to occur when the driver was talking on the cell phone, and four were scheduled to occur when the driver was not talking on the cell phone. The exact timing of these events varied from session to session. During the session, two phone calls were made to the participants, and they were in conversation for a total of 5 min during a 10-min session. The timing of the call was varied so half of the time the first call occurred at the start of the trip and half of the time it occurred 2.5 min after the start of the trip. The cell phones were placed either on the passenger seat or next to the driver before starting the session. Cell phone placement was determined by asking participants how they preferred to answer the phone call in a vehicle.

Conditions and Design

A concurrent multiple baseline design across participants with a reversal to test for maintenance was used to evaluate the efficacy of feedback, prompting, and goal setting on driver following headway and hard braking. An alternating treatments design was used to compare the effects of cell phone use with nonuse on driving performance during baseline, intervention, and maintenance.

Baseline. No prompts or feedback was provided to drivers except for the general instructions noted above.

Training. Training was initiated by a single 30-min session, during which participants were taught how to measure following headway and were instructed to follow the lead vehicle by 3 s or more during the entire 30 min. All four participants described how to measure following headway when asked; however, training was conducted (without the use of cell phones) to ensure that the participants could measure this reliably. The participants were asked to count when the rear bumper of the lead vehicle crossed a stationary object and to stop counting when the front bumper of the vehicle they were driving crossed the same stationary object. The stationary objects that were programmed in the session included houses, buildings, trees, cars, and road signs. The participants counted the seconds aloud in a format of "one one thousand" for the first 10 min. For the last 20 min, the participants were asked to count covertly to promote a transfer from counting following headway to gauging actual distance of following a lead vehicle. The experimenter used a stopwatch to time the following headway for the entire 30 min and gave the participants real-time feedback of their actual following headway approximately every 15 s during the course of the training procedure, depending on the location of convenient stationary objects in the scenario. Vocal feedback was stated in the form of seconds by the experimenter. For example, if the participant followed at 4 s, this time was stated aloud by the experimenter. The training procedure was terminated when the participants mastered following by 3 s or more for 90% of the scenario. All four participants mastered this criterion in the first session.

Intervention. Scenarios were identical to those driven during baseline. At the start of each session, the experimenter prompted the participant to follow the lead vehicle by 3 s or more when conversing on the cell phone. Participants received vocal feedback of the mean cell phone following headway (in seconds) at the end of each session and then again at the beginning of the next session if it occurred on a different day. Participants were required to initial a checklist after every feedback session and before each session on subsequent days of the intervention to remind the drivers of their following headway on the previous session and to ensure that the participants were given feedback. During the withdrawal phase, procedures were identical to those in baseline.

RESULTS

Data on following headway for each participant during the baseline, intervention, and withdrawal phases are presented in Figure 1. Data from the training session are not shown. During baseline, Participants 1, 2, and 3 followed the lead vehicle with a mean following headway of less than 2 s during cell phone use and nonuse. Participant 4 had a baseline mean following headway of 1.9 s during cell phone use and 2 s when not using the cell phone. After introduction of the intervention, following headway for all participants increased to above 3 s during cell phone use and nonuse. During the withdrawal phase, following headway for Participants 1 and 4 decreased to baseline levels. For Participants 2 and 3, following headway decreased during the withdrawal, although not to baseline levels. It should be noted that none of the participants followed more closely during baseline when talking on the cell phone. Furthermore, feedback had a similar effect on following headway whether or not participants were on the cell phone.

Mean braking deceleration is presented in Figure 2. It should be noted that hard braking is typically defined as braking deceleration of 9 ft/s^2 or more. During baseline, all four participants were braking at levels above 9 ft/s^2 during both cell phone use and nonuse. After the intervention was introduced, mean braking during cell phone use decreased immediately below the hard braking measure of 9 ft/s^2, except for Participants 1 and 4 when they were off the cell phone. Braking deceleration for Participant 1 initially increased during both cell phone use and nonuse but eventually decreased and stabilized for the remainder of the intervention phase. During the withdrawal phase, Participants 1 and 2 increased mean braking deceleration to hard braking levels, although not to levels observed in baseline. For Participants 3 and 4, mean braking deceleration increased back to the hard braking levels observed in baseline. The incidence of hard braking during baseline and intervention did not appear to be influenced by cell phone use.

DISCUSSION

An intervention that consisted of feedback, prompting, and goal setting increased following headway and decreased hard braking. However, performance was not maintained after withdrawal of the intervention. These results suggest that teaching students to increase following headway during situations of high driving workload could decrease their risk of crashes but that further research is needed on interventions that will maintain these improvements. Participants were young drivers with 2

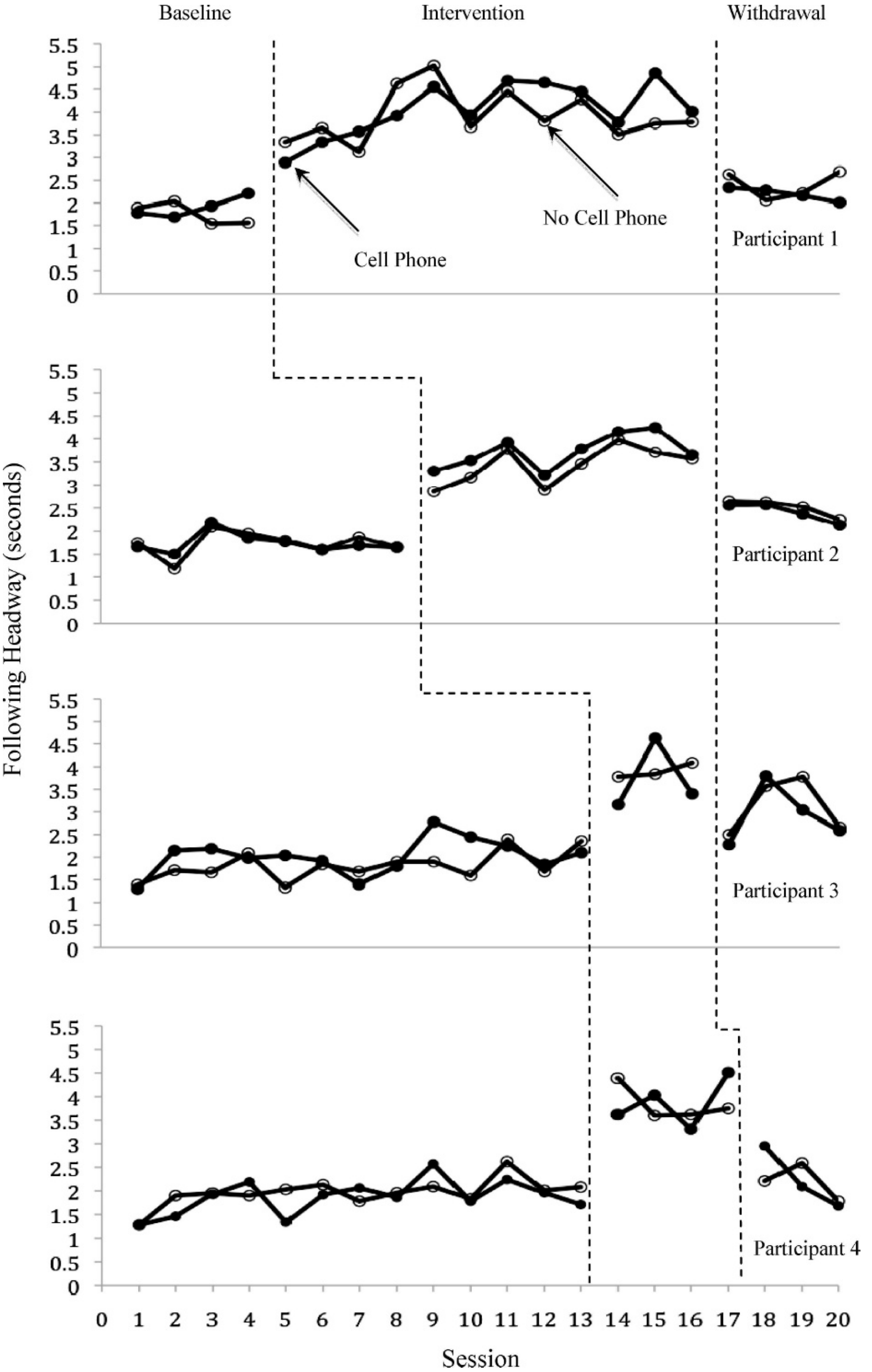

Figure 1. The following headway (in seconds) for each participant when talking and not talking on the cell phone during each session of the experiment.

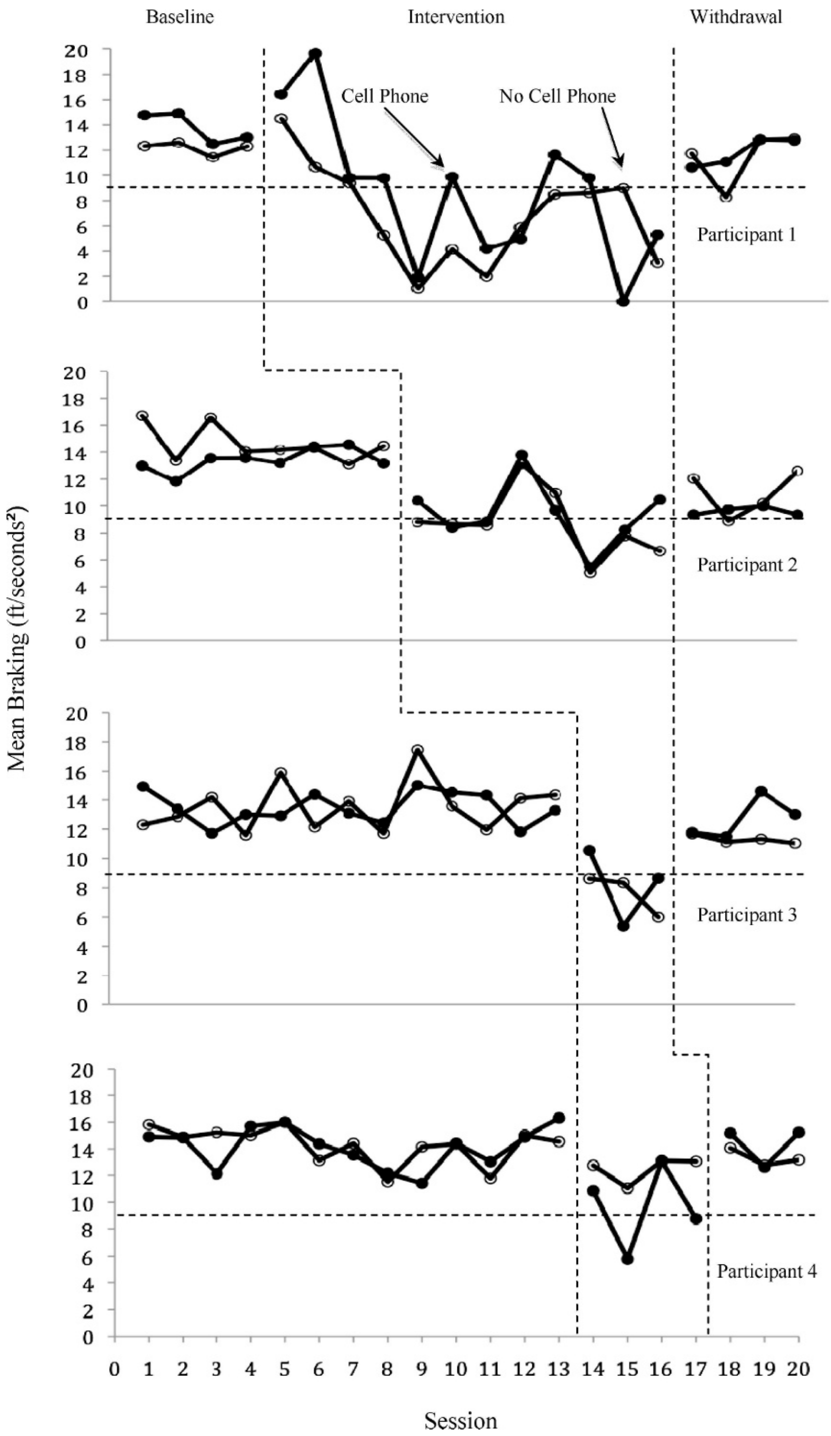

Figure 2. Mean braking (in ft/s^2) for each participant when talking and not talking on the cell phone during each session of the experiment. The dashed horizontal line shows the threshold for hard braking.

or 3 years of driving experience, who followed extremely closely (short following headway) in baseline. It is interesting to note that younger drivers, on average, have been documented to follow a lead vehicle more closely than other drivers (Sarkar & Andreas, 2004). These authors suggested that younger drivers may overestimate their driving ability or fail to see the risk in engaging in risky behaviors such as following too closely.

The term *workload* refers to the effort a person invests in his or her performance while carrying out a task. Both driving and conversational workload may vary over a wide range of values. For example, a heated conversation would increase conversational workload, whereas an increase in traffic would increase driving workload. It is interesting to note that after the first intervention session, Participant 1 commented that he was sorry he had a difficult time counting following headway while having an ongoing conversation because he was required to do too many things (i.e., drive, talk on the cell phone, count seconds to himself in following time). Nonetheless, he continued to talk during the session. Although hard braking increased significantly for this participant during cell phone use when the intervention was first introduced, hard braking decreased during subsequent sessions of the intervention. These results suggest that the decrement in performance that occurs with cell phone use may be directly related to driver workload. As the participant learned the task, the workload was reduced and the decrement disappeared. This experience may be similar to other unfamiliar tasks such as using a global positioning system while driving. Initially, the system may be difficult to use, but with continued practice, the task becomes effortless as fluency develops. It should be noted that data on following headway and hard braking for the other participants did not suggest a workload problem, and none of the participants stopped talking during any of the sessions nor did they comment about task difficulty.

One objective of the present study was to emulate as much as possible a real-life conversation. Many studies that have shown performance decrements associated with cell phone use have used cell phone tasks that are not representative of a natural cell phone conversation (e.g., experimenter-paced operations in which the participant had limited time to answer a math equation; McKnight & McKnight, 1993). The current study did not show an effect of the cell phone intervention, and this result could have been due to the drivers' ability to adjust their behavior to compensate for driver workload. Shinar et al. (2005), for example, investigated the effects of cell phone conversations on driving by using repeated measures of simulation driving while drivers were involved in hands-free cell phone tasks. Across the course of five sessions of driving and using the cell phone, performance improved on most of the driving measures and interference from the phone task was greater during the artificial tasks.

The advantages of a simulator study are that the environment can be controlled and all participants can be subjected to the same situations. Different road and weather situations can be studied without having to wait for them to occur in a natural environment, and dangerous situations can be studied without exposing participants to risk. Results obtained in a simulator are often found to be valid for at least certain aspects of real-world driving (e.g., Reed & Green, 1999; Tornros, 1998; Tornros, Harms, & Alm, 1997). Future research should focus on ways to validate the performance measures in this simulation study by obtaining probe measures with real driving scenarios.

Although research assistants tried to emulate real phone conversations in the current study, data were not collected on the integrity of the cell phone calls. None of the research assistants noticed any difference in the drivers' latency to respond during the conversations, but no data were collected on this measure. These limitations should be addressed in future research.

It is possible that more extended training or a self-monitoring component would result in better maintenance. Behavioral self-monitoring involves repeatedly observing, evaluating, and recording one's own behavior (Olson & Winchester, 2008). Self-monitoring has been previously examined in the safety literature for lone workers, as well as in the traffic literature. Because driving is a behavior that often occurs when the subject is alone, future driving studies could examine self-monitoring procedures. For example, a beep at regular intervals could signal to the driver to observe his or her following headway. Future studies should investigate other interventions or added components to this intervention that would properly inform the driver of the associated risks of close following while driving. For example, an educational component that teaches the relation between close following headway and an increased risk of a crash might improve our intervention. Also, we only prompted the drivers to use a set following headway and did not provide any immediate consequences for failing to follow the prompts. One practical intervention for future research is the preventive safety measuring device that has been incorporated into Volvo cars. This is a collision warning system with an automatic brake that makes the car brake if the driver does not react when a rear-end collision with a moving or stationary vehicle is going to occur. It uses both radar and a camera to detect vehicles in front of the car. If the car approaches another vehicle from behind and the driver does not react, a red warning light flashes and an audible signal can be heard.

Finally, few studies have evaluated the relation between following headway and hard braking. In the current study, following headway had an inverse relation to hard braking. Future research should evaluate this relation to determine whether the following headway or following time rules taught to new drivers provide optimum headway, regardless of fatigue, driving experience, and road conditions, and if the rules taught need to be modified to accommodate individual differences.

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